RESEARCH COMMUNICATION

# Mandibular Reconstruction with Vascularized Osseous Free Flaps: a Review of the Literature

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## Abstract

**Purpose: This article reviews a few of the commonly used types of vascularized osseous free flaps in maxillofacial reconstruction, which still represents the gold standard of restoration. We also discuss the developing concepts in maxillofacial reconstruction. Recent findings: Most of the literature reconfirms the established patterns of reconstruction with the aid of vascularized osseous free flaps. This method of free-tissue transfer is also feasible in cases of osteoradionecrosis or bisphosphonate-related osteonecrosis of the jaw. These flaps are also suitable for prosthetic restoration using osseointegrated dental implants. Summary: Vascularized osseous free flaps still remain the standard of care. Improvements upon the free-tissue transfer method employing vascularized osseous free flaps, such as distraction osteogenesis, tissue engineering, and imaging techniques, currently require further development, but these technologies could lead to improved outcomes of maxillofacial reconstruction in the near future.**

**Key words:** Mandibular reconstruction - vascularized osseous free flaps

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## Introduction

The modern era of maxillofacial reconstruction involving the use of vascularized osseous free-tissue transfer began in 1975 when Taylor et al. described the microvascular fibula free flap (Taylor et al., 1975). The goals of maxillofacial reconstruction are the restoration of both form and function, which require the appearance, mastication, deglutition, speech, and oral competence to be considered (Hidalgo and Pusic, 2002; Valentini et al., 2005). The highly visible position of the maxillofacial area places a large emphasis during reconstruction on using tissue coverage that imitates the resected native tissue with regard to both form and function (Kim et al., 2008).

Vascularized osseous free flaps are frequently used in the reconstruction of mandibular defects, especially those greater than 5 cm in diameter (Foster et al., 1999). Three general choices for osseocutaneous flaps are fibula, iliac crest, and scapula flaps. In this article, we review some of the commonly used types of free osseous flaps and discuss the current and developing concepts in mandibular reconstruction.

## Materials and Methods

*Search methods and data collection*

Data for this review were identified through a comprehensive search of PubMed on March 31, 2011 (without filtering, from 1969 to March 30, 2011). The resulting abstracts and titles identified by the search were evaluated by one of the authors to exclude all irrelevant studies. Study details and outcome data were collected by one of the authors. Of those studies, we found almost 60 articles related to current or developing concepts in maxillofacial reconstruction.

*Review of vascularized osseous flaps*

i) Iliac crest flap

The vascularized iliac crest free flap based on the deep circumflex iliac artery has become a useful option for microsurgical reconstruction of the mandible (Taylor et al., 1979a; Taylor et al., 1979b; Franklin et al., 1980; Kang et al., 2008). It offers a good length of thick, strong, tall bone that is of sufficient stock to support an osseointegrated implant within a reasonable shape match for the hemimandible. However, it is less adaptable for composite mandibular reconstructions, since its skin paddle is not reliably supported by the deep circumflex iliac artery and is difficult to fit because of its limited mobility, excessive bulk, and short pedicle (Salibian et al., 1985). The slightly elevated donor-site morbidity (e.g., abdominal hernia) associated with the iliac crest flap has resulted in it becoming less popular. However, it remains a feasible second-line option for structural reconstruction of the mandible (Kim et al., 2008),

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because the esthetic and functional results of the iliac crest flap may be indistinguishable from those of the free vascularized fibula flap (Shpitzer et al., 1999).

ii) Scapula flap

The clinical use of the scapula free flap was first reported in 1986 (Swartz et al., 1986). Since then, it has remained a popular choice for the complex microsurgical reconstruction of the maxillofacial area due to its ability to tolerate multiple osteotomies with a thin blade and the potentially large skin paddle (Siemionow et al., 2006; Sakurai et al., 2005).

The scapula flap lacks the bone stock available with the iliac crest flap, but it provides 11–12 cm of excellent mandible replacement while providing a vastly superior soft-tissue paddle for the reconstruction of large complex defects (Wang et al., 2011). Furthermore, its resistance to atherosclerosis renders it a good alternative for patients with this condition when the adequacy of the blood supply is uncertain (Brown et al., 2010). Composite scapula flaps are best suited in cases of anterior mandibular resections that require extensive reconstruction of the tongue and soft tissue, posterior mandibular defects that require extensive oropharyngeal resection including that of the soft palate, and complex defects that involve oral resection and resection of the facial skin, including those caused by osteoradionecrosis (ORN) (Brown et al., 2010).

However, the difficulty of intraoperative positioning makes the procedure more tiresome than when using the iliac crest flap (Kim et al., 2008). Moreover, its thick skin paddle, short vascular pedicle, and limited availability of bone segment remain its principal disadvantages (Swartz et al., 1986). Moreover, the donor-site morbidity may be high, with large scars extending across the back (Kim et al., 2008).

iii) Fibula flap

The vascularized free fibula flap is the most versatile and reliable option for the microsurgical reconstruction of large mandibular defects (Wallace et al., 2010). The fibula flap was introduced in 1975 (Taylor et al., 1975), and Hidalgo confirmed in 1989 that it could withstand multiple osteotomies and successfully recreated the subtle mandibular contour (Hidalgo et al., 1989). Fibula osteocutaneous flaps provide up to 25 cm of bone and a skin paddle as large as 10–20 cm (Wang et al., 2011). The bone stock of the fibula flap combined with its bicorticocancellous structure make it excellent for the placement of osseointegrated implants (Wallace et al., 2010; Barber et al., 1995). The thin and pliable skin paddle can also be harvested as a neurosensory flap, and a vascularized nerve graft can be harvested with the fibula flap (O'Leary et al., 1994). Multiple skin paddles can be harvested within the flap, including those classically based on the septocutaneous and the osteomusculocutaneous peroneal perforators (Daya 2008). The donor-site location of the fibula allows two teams to work simultaneously at the donor and recipient sites, which reduces the operative time (Wallace et al., 2010).

Initial problems with the fibula flap largely arose from the limited height of the reconstructed mandible, which necessitates long abutments on the osseointegrated implants, thus increasing the inappropriate crown-to-implant ratio and increasing the potential for consequent implant failure (Wang et al., 2011). However, the fibula replacement can simply be positioned more superiorly in the mandibular defect or can be double-barreled to increase its load-bearing capacity (Chang et al., 2008; Bahr et al., 1998).

*Radiation therapy and ORN*

Radiation therapy can lead to both early- and late-onset tissue reactions (Pogrel et al., 1997; Granström et al., 1992). The late reactions are typical radiation-induced fibrosis and bone demineralization, in conjunction with a diminished ability to resist infection. The subsequent xerostomia reduces the production of saliva and makes it more viscous. This effect is not temporary since the salivary glands are permanently damaged. The irradiated osseous structure is more liable to infection because of diminished perfusion. Moreover, radiation causes endarteritis, resulting in tissue hypoxia, hypocellularity, and hypovascularity, which cause tissue collapse, resulting in chronic nonhealing wounds (Marx 1983).

ORN has been described as bone exposure within a field of radiation that has not healed with conservative therapy after a 3-month period (Alam et al., 2009). While there are few reports on the pathophysiology of the process, it seems to involve at complex interaction between hypoxic and hypovascular local tissue environments and chronic infectious factors (Goldwaser et al., 2007; Celik et al., 2002). It is potentially one of the most debilitating complications of radiation therapy for patients undergoing treatment for oral cancer. Once the tissue necrosis progresses to the point of fistulization or pathologic mandibular fracture, surgical resection of the nonviable tissue remains the treatment of choice. Moreover, surgeons are challenged by deficiencies of the wound healing inherent to irradiated tissues.

In an effort to improve success rates in patients treated with radiation, various vascularized osseous flaps have been used to improve the vascularity of the recipient bed in preparation for the subsequent bone graft (Dufresne et al., 1987). Hirsch et al. compared the outcome and complications between patients undergoing vascularized osseous flap reconstruction for ORN and similarly reconstructed patients who received radiation therapy but did not develop ORN, as well as with unradiated controls (Hirsch et al., 2008). In their study the overall flap survival was 88%, and did not differ significantly between ORN (86%), no ORN (87%), and controls (90%); the complication rates also did not differ between the three groups. These results suggest that free flap transfers using the fibula, iliac crest, and scapula are viable options for advanced mandibular ORN.

*Dental implants*

Dental implants play an important role in the rehabilitation of masticatory function, allowing the fixation of prosthetics and protecting the existing bone by providing an approximation of physiologic bone healing (Boyne et al., 1971). The characteristics of the lining mucosa covering transferred osseous tissue varies significantly between healthy patients, with the attached gingiva often not being present and the thickness of the mucosa exceeding that of healthy gums, predisposing the patient to the development of periodontal pockets.

Blake et al. studied the susceptibility of implants to inflammation following autogenous bone transplantation and evaluated the association between the soft-tissue response and different types of autogenous bone grafting (Blake et al., 2011). They reported that the rate of peri-implant inflammation varied between 9% and 38% depending on the type of reconstruction. Rates of 16.3–24.1% were seen for mucositis, while 30–70.9% of sites exhibited no inflammation. There were high rates of soft-tissue inflammation adjacent to implants in autogenously transplanted bone, and it was found that the choice of donor site and the mode of transplantation together appeared to influence the development of peri-implant inflammation. Furthermore, the microsurgically reanastomosed fibula seemed to be most resistant to the inflammatory process, followed by reanastomosed iliac crest, free iliac crest, and free fibula. Thus, the microsurgically reanastomosed fibula appears to be the best suited for maxillofacial reconstruction in terms of the long-term incidence of peri-implantitis, followed by the microsurgically reanastomosed iliac crest flap. The scapula bone stock, which relies on the lateral edge of the scapula, is often too thin for use in implants (Mücke et al., 2011).

In the case of oral rehabilitation with dental implants in irradiated free transferred tissue, there is no reliable consensus regarding the effects of the level of irradiation (Garrett et al., 2006). However, Raoul et al. suggested that implant placement should be avoided in areas that have received radiotherapy doses of more than 50 Gy (Raoul et al., 2009). Alam et al. also reported that the risk of developing ORN is significantly higher in patients receiving total radiotherapy doses exceeding 50 Gy (Alam et al., 2009).

Raoul et al. reported that implant loss occurred only in 1 irradiated vascularized fibula flap among a total of 18 implants placed in 6 patients, representing a success rate of 94% (Raoul et al., 2009). Salinas et al. reported a 72.5% osseointegration rate for 51 implants placed in 22 patients (Salinas et al., 2010). They found that the radiation dose had statistically significant effect on implant success.

*Bisphosphonate-related osteonecrosis of the jaw*

Bisphosphonate rarely induces osteoclast apoptosis, and generally only at high concentrations (Kimmel 2007). Bisphosphonate may remain in bone for years, eventually causing avascular osteonecrosis, loss of bone matrix, and accumulation of nonviable osteocytes (Allen and Burr, 2009). Although the causality remains controversial, the available epidemiological and experimental evidence supports an association between bisphosphonate use and osteonecrosis of the jaw (Dodson, 2009). Therefore, this clinical entity is currently referred to as bisphosphonate-related osteonecrosis of the jaws (BRONJ) (Ruggiero et al., 2009).

The risk of acquiring BRONJ appears to be greater among patients undergoing intravenous (IV) treatment and those treated for longer durations (Bamias et al., 2005). Ruggiero et al. estimated that the incidence of BRONJ secondary to IV bisphosphonate therapy is between 0.8% and 12%, whereas that among users of oral bisphosphonates is considerably lower at between 0.01% and 0.06% (Ruggiero et al., 2009).

The diagnosis of BRONJ requires (1) current or previous treatment with a bisphosphonate, (2) exposed bone in the maxillofacial region that has persisted for more than 8 weeks, and (3) no history of radiation therapy to the jaws (Ruggiero et al., 2009). Patients with BRONJ typically present with exposed and necrotic bone, oral mucosa and skin breakdown with fistula tracks, chronic soft-tissue infection, purulence, and pain (Ruggiero and Drew, 2007).

Seth et al. demonstrated that vascularized bone graft reconstruction with the fibula free flap in 11 patients offered a high success rate of bone union and fistula closure, and should therefore be offered to selected patients with advanced cases of BRONJ (Seth et al., 2010). Several other small case series have collectively described 12 patients with a follow-up of 1 year or more treated in a similar fashion with fibula free flap reconstruction (Engroff and Kim, 2007; Nocini et al., 2009; Ferrari et al., 2008; Mucke et al., 2009). Postoperative complications included fistula (n=3), prolonged infection (n=1), and hematoma (n=1). All of the complications resolved with conservative therapy, except for one fistula, which required a pectoralis major flap. There were no flap failures. One patient had a short-term recurrence at a resection margin that may not have been cleared of disease. Importantly, no significant perioperative morbidity or mortality was noted. The findings of these reports support the safe and effective role of microvascular fibula flap reconstruction of segmental mandibulectomy defects in selected patients with advanced and refractory BRONJ.

## Results

Most of the literature reconfirms the established patterns of reconstruction with the aid of vascularized osseous free flaps. This method of free-tissue transfer is also feasible in cases of osteoradionecrosis or bisphosphonate-related osteonecrosis of the jaw. These flaps are also suitable for prosthetic restoration using osseointegrated dental implants.

## Discussion

Reconstruction of the maxillofacial area often requires multiple approaches and procedures. Postoperative radiation therapy increases the probability of complications such as fistula formation or tissue necrosis, and limits the availability of local flaps.

Distraction osteogenesis could be a viable alternative treatment in maxillofacial reconstruction. This technology is a process in which bone adjacent to the defect is osteotomised and gradually distracted with the aid of a mechanical device, thereby allowing new bone formation in the gap between the two ends. Sacco and Chepeha reported that distraction osteogenesis has been a successful treatment option in patients who have not received radiotherapy in the setting of mandibulectomy (Sacco and Chepeha, 2007). However, the major challenge surrounding the use of this technology in maxillofacial reconstruction will again be the effect of radiotherapy on the regenerated bone in patients who have previously received or will need radiotherapy as part of their treatment.

Advances have also been made in the field of tissue engineering for both bone and the oral mucosa. Herford et al. reported on the application of recombinant human bone morphogenetic protein (rhBMP)-2 alone with a collagen carrier and without concomitant bone materials in 14 patients with mandibular defects resulting from neoplastic diseases or secondary to osteomyelitis (related to bisphosphonates or irradiation) (Herford and Boyne, 2008). Successful osseous restoration of the edentulous area and subsequent prosthodontic treatment were achieved in all of the patients. Herford et al. argued that bone formation in the operative area could be palpated at the end of 3–4 months, and identified radiographically at the end of 5–6 months (Herford and Boyne, 2008). However, although there have been some successful outcomes in the aforementioned isolated case series, rhBMP-2 should not be applied in routine clinical practice until studies provide further data supporting its use (Bell and Gregoire, 2009).

In recent years, advances in imaging techniques (spiral computed tomography and three-dimensional imaging) and associated technologies (i.e., stereomodels) have been used as clinical tools to assist surgeons in accurately designing operative plans and procedures and for achieving improved outcomes (Gellrich et al., 2002). Hou et al. reported the results of mandibular reconstruction in seven patients with the aid of preoperative three-dimensional model osteotomy planning and vascularized fibula osteomyocutaneous flaps (Hou et al., 2011). A prefabricated anatomic model was used, and a 0.5-mm-thick titanium minimesh was shaped and cut to size to achieve a three-dimensional shape that best fit the contours of the defects. This technique, using a model based on computer-aided design/computer-aided manufacturing and rapid prototyping, could provide a successful cosmetic and functional result. Meanwhile, Liu et al. investigated the use of a computer-assisted resin template as a messenger in seven patients who needed maxillofacial reconstruction involving a fibula flap, and evaluated a quantitative and objective method for evaluating the repeatability of preoperative planning (Liu et al., 2009). The mean repeatability was 96.5% within 2 mm in isolated bone and 89.9% in the reconstructed mandible or maxilla. They proved that using a resin template based on the technique of virtual planning and rapid prototyping allows the results of computer modeling to be transferred to bedside surgical procedures. These techniques can reduce the dependency on the personal experience of each reconstructive surgeon, thereby providing a more predictable reconstruction outcome.

In summary, vascularized free-tissue transfers have become the most feasible option for the reconstruction of maxillofacial defects. Free flaps can provide superior esthetic and functional results in the maxillofacial region. Such flaps have an abundant blood supply and provide the flexibility for appropriate orientation and insertion. There are continuing advances in techniques such as distraction osteogenesis, tissue engineering, and treatment planning with the aid of imaging techniques, and these will ultimately improve the outcomes in maxillofacial reconstruction. However, more research is still required to improve the quality of treatment for maxillofacial defects.

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